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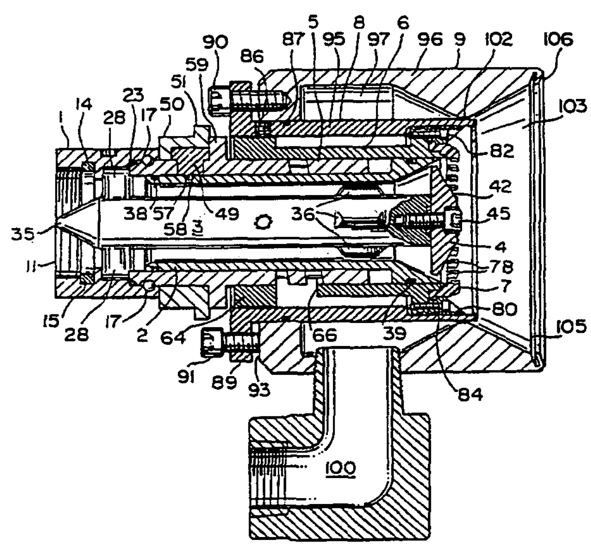

(57) Abstract

An air/water snowmaking gun includes a pair of concentric shells (8, 9) defining an annular compressed air chamber (97) and an annular discharge slot (102), and a central water nozzle for spraying an annular stream of water droplets into the center of the stream of air for mixing therewith downstream of the gun. The water nozzle is controlled by a valve (2, 4) which effects volume control, and a turbine (7) is used to effect self-atomizing of the water into droplets. The pattern of the water, i.e. cylindrical or flaring is controlled at the discharge end of the nozzle by a pattern control sleeve (6). The water and air are discharged separately from the gun with their own momentum energy, and only after leaving the gun is there a gradual combination of the two in the plume and entrained ambient air, whereby, temperature permitting, sufficient heat is removed to form snow.

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SNOWMAKING GUN

This invention relates to a snowmaking gun, i.e. a gun for producing artificial snow.

In general, the basic process for producing artificial snow (involving the formation of ice crystals) is a heat exchange process involving heat rejection. When sufficient heat has been removed under proper temperature conditions, small droplets of water will freeze. There are four major factors affecting the removal of heat from water droplets, namely:

(1) the flight time of the droplets,

(2) the temperature differential between the ambient air and the water droplets,

(3) the relative humidity of the air and the barometric pressure, and

(4) the diameter and surface area of the droplets.

The basic types of snowmaking apparatuses in use today include the so-called compressed air type and the fan type. In a compressed air apparatus, air and water are supplied to snow guns for atomizing, projection and distribution of an air/water mixture. A fan type apparatus includes a large tubular casing containing a fan for producing a large volume of air. Water is atomized hydraulically and injected into the air stream produced by the fan. Direct nucleation is required with this type of apparatus. All snowmaking apparatuses must achieve the same objectives, namely the atomizing of water droplets, the projection of the droplets into air so that they can freeze, and the nucleation of water droplets to enhance freezing in the minimum time at the highest possible temperature. Moreover, it is desirable to achieve the foregoing as economically as possible.

In the vast majority of compressed air type apparatuses, air and water are mixed prior to being discharged from a nozzle as a mixture. The compressed air facilitates internal mixing and nucleation. The high velocity of the mixture results in freezing of smaller droplets to create nuclei. The compressed air also provides most of the force

necessary to project the droplets into the air. The secondary or entrained ambient air provides the largest part of the cooling required to convert the water droplets into ice particles.

Both type of apparatus has its advantages and disadvantages. Compressed air snow guns are lightweight, structurally simple, easy to operate, store and transport, relatively problem free on the slopes, more efficient in marginal temperatures, and better adapted to steep and narrow slopes. However, such guns are noisy, result in high energy consumption and costs, and experience higher water evaporation losses. Fan type machines have lower energy consumption and costs, higher snowmaking capabilities, lower noise level and less water evaporation than compressed air/water guns. Unfortunately, fan type machines are large and heavy, difficult to use on steep slopes, and are more complicated to operate, requiring better skills than the compressed air/water gun.

Comparison of a fan type machine (see U.S. Patent No. 4,711,395, which issued to the present inventor on December 8, 1987 with the best compressed air guns resulted in the conclusion that the fan type machine converts water into snow while using less than one fifth the energy required by the best air/water guns operating at peak efficiency.

As a general principle, the quantity of snow produced is directly proportional to the quantity of water employed. However, at any given temperature and humidity, and for a specific volume of air, only limited quantities of water may be sprayed into the air and result in high quality, dry snow. Thus, for any snowmaking machine, there is a trade off between snow quantity and quality which vary in accordance with climate conditions. As mentioned above, the production of artificial snow is a heat exchange process in which the actual heat exchange occurs at a distance from the apparatus or gun. Thus, a relatively important part of the system is the plume of air and water interacting with ambient air outside of the apparatus. In order to ensure efficient

snowmaking, it is important to ensure that (1) proper mixing of water droplets and air occurs in the plume outside the machine, (2) the water droplets remain airborne for a sufficient period of time to become frozen, and (3) energy consumption be kept to a minimum.

Recently, there has been a great deal of activity in the area of artificial snowmaking. In general, the effort has been concentrated in the area of mixing within the machine, i.e. of creating a mixture of air and water within the gun. Very little effort has been addressed to increasing the interaction of air and water in the plume itself which is acknowledged to be most important area in the heat exchange process.

For a given nozzle, the degree of atomization is a function of the supply pressure of the fluids, and the mass ratio of the air and water. Existing compressed air guns rely on the production of homogeneous mixture in the guns. With such guns, the air and water must be introduced at approximately the same pressure (70 to 150 psi). Once a discharge orifice size has been chosen, the operating conditions and characteristics with respect to available air/water ratios for given fluid pressures are established. Moreover, the use of fixed orifices for air and water means that water can be adjusted only by varying the water pressure. At marginal temperatures, guns operate with minimum water flow, i.e. minimum water pressure. In such circumstances, when it is most needed, the full potential momentum energy of the pressurized water supply is not utilized.

The object of the present invention is to provide a snowmaking gun of the compressed air/water type which maintains the advantages of small size, weight and portability while adding positive features normally associated with fan type machines, namely low energy consumption and high snowmaking capabilities.

Accordingly, the present invention relates to a snowmaking gun comprising:

(a) casing means including

(i) outer shell means,

(ii) inner shell means defining an air chamber and an annular air discharge slot with said outer shell means;

(b) tube means extending substantially entirely through said inner shell means for receiving water from a source of water under pressure and for discharging the water from the gun;

(c) valve means at the outlet end of said tube means for controlling the volume of water flowing through said tube means, and shaping the water into an annular stream of small droplets for discharge into the center of the annular stream of air exiting said air discharge slot for mixing with said stream of air downstream of the discharge end of the gun for producing snow, temperature permitting.

The invention will be described in greater detail with reference to the accompanying drawings, which illustrate a preferred embodiment of the invention, and wherein:

Figure 1 is a side elevational view of a snowmaking gun in accordance with the present invention;

Figure 2 is a longitudinal sectional view of the gun of Fig. 1.

Figure 3 is an exploded, partly sectioned, side elevational view of a coupler, guide rod and a water tube used in the gun of Figs. 1 and 3;

Figure 4 is a side view of the coupler of Fig. 3;

Figure 5 is an end view of the coupler of Fig. 4 as viewed from the right;

Figure 6 is a perspective view of the guide rod of Fig. 3 on a larger scale;

Figure 7 is an exploded, partly sectioned side elevational view of a nozzle body, a pattern control sleeve and a turbine used in the gun of Figs. 1 and 2;

Figure 8 is a perspective view of a control ring used on the nozzle body of Fig. 7;

Figure 9 is a perspective view of a cam used in the nozzle body of Fig. 7;

Figures 10 and 11 are schematic partly sectioned side views of the discharge end of the pattern control sleeve of Fig. 7;

Figure 12 is a perspective view of a threaded insert and clip used in the nozzle body and pattern control sleeve of Fig. 7;

Figure 13 is an end view of the turbine of Fig. 7;

Figure 14 is an exploded side view of inner and outer shells used in the gun of Figs. 1 and 2; and

Figure 15, which appears on the second last sheet of drawings, is a partly sectioned side view of the shells of Fig. 14 in the assembled condition.

It should be noted that Figs. 3, 7 and 14 placed end-to-end with their centerlines aligned illustrate the complete apparatus in the disassembled condition.

Referring to Figs. 1 and 2 of the drawings, the main elements of the snowmaking gun include a coupler 1, a water tube 2, a guide rod 3, a valve body 4, a nozzle body 5, a water pattern control sleeve 6, a plastic turbine 7, an inner shell 8 and an outer shell 9.

As best shown in Figs. 2 to 5, the coupler 1 is defined by a tubular body 10 with an internally threaded inlet end 11 for receiving an adapter 12 and a pipe 13, which connects the gun to a source of water under pressure (not shown). An annular groove 14 in the inlet end 11 of the coupler 1 receives a rubber seal 15. The coupler 1 is connected to one end of the nozzle body 5 (Fig. 7) by a plurality of ball bearings 17 (forty in this case) which are inserted through an opening 18 into complementary, opposed, annular grooves 19 and 20 in the coupler 1 and the nozzle body, and a set screw 22. If the screw 22 is not tightened against the body 5, the latter can rotate. However, for

normal use, the screw 22 is tightened to lock the two elements together. An O-ring 23 is sandwiched between a shoulder 24 in the coupler 1 and the bevelled inlet end 25 of the nozzle body 5.

A pair of diametrically opposed, concave grooves 27 (Figs. 3 and 5) are provided in the coupler 1 for receiving a pair of lugs 28 on the inlet end of the guide rod 3 which prevents rotation of the rod in the gun. Shoulders 30 on one side of the lugs 28 bear against the inlet end 25 of the nozzle body 5 when the gun is assembled (Fig. 2). The elongated body 31 of the rod 3 extends through most of the length of the tube 2 stopping short of the internally flaring discharge end 33 thereof. A conical tip 35 on the inlet end of the rod smoothly diverts the flow of water along the length of the rod. The rod 3 is centered in the tube 2 by four vanes 36 near the downstream end of the rod in the direction of water flow. The vanes 36 are spaced equidistant apart around the rod 3.

As best shown in Fig. 2, the tube 2 is slidably sealed in the body 5 and the water pattern control sleeve 6 by a pair of O-rings 38 and 39, respectively. It will be noted that the tube 2 extends beyond the downstream end of the body 5, the larger diameter discharge end 33 thereof slidably engaging the discharge end 40 of the sleeve 6. The volume of water discharged from the tube 2 is controlled by a valve, which includes a valve body defined by a disc 4. The disc 4 (Fig. 3), which may have a bevelled trailing edge 42 (Fig. 2) is connected to the downstream end 43 (Fig. 6) of the rod 3 by a screw 45. Shims 46 (Fig. 3) are provided in an annular recess 47 in the end of the 4. By moving the tube 2 longitudinally on the rod 2, the opening between the disc 4 and the tube 2 can be varied to control the volume of water discharged from the tube.

Longitudinal movement of the tube 2 is effected using the nozzle body 5, a cam 49 (Figs. 7 and 9) and a control ring 50 which includes an annular flange 51. A pin 52 extends through one side of the body 5 into a short

longitudinally extending recess 53 (Fig. 3) in the tube 2, permitting longitudinal movement of the tube while preventing rotation thereof in the body 5. The cam 49 is slidably mounted in a semicircular slot 54 in the body 5.

Referring to Fig. 9, the cam 49 includes an arcuate body 55 conforming in curvature to the side wall of the body 5. Flanges 56 extend outwardly from the sides of the body 55 for sliding on the body 5 when the body 55 of the cam 49 is inserted into the slot 54. A generally oval lug 57 on the inner surface of the body is inclined or angled with respect to the longitudinal axes of the cam body 55 and the slot 54. When the gun is assembled, the lug 57 extends into a short inclined groove 58 (Figs. 2 and 3) in the side of the tube 2. Thus, because the tube 2 cannot rotate in the body 5, rotation of the cam 49, i.e. movement of the cam in the slot 54 causes longitudinal movement of the tube 2 in the body 5 to adjust the valve opening.

Rotation of the cam 49 is effected using the ring 50, which is best shown in Fig. 8. The annular external flange 51 of the ring 50 bears against an annular flange 59 on the nozzle body 5 for maintaining the ring 50 in contact with the cam 49. A recess 60 in the interior of the ring 50 engages the outer portion of the cam 49 (exterior to the body 5) for moving the cam longitudinally in the slot 55. A rod-shaped handle 61 is used to rotate the ring 50. The threaded end 62 of the handle extends into the ring 50 for slidably receiving the latter on the body 5.

The pattern control sleeve 6 is mounted on the nozzle body 5. The position of the sleeve 6 on the body 5 can be adjusted to change the pattern of the water discharged from the gun. The water pattern can be more or less cylindrical (Fig. 10) or diverging (Fig. 11) depending upon the location of the sleeve 6 in relation to the tube 2. Teh pattern is adjusted by moving the sleeve 6 relative to the fixed nozzle body 5.

The control pattern sleeve 6 includes a cylindrical, tubular body 63 with a wide, annular flange 64 at

the inlet end thereof and a narrow annular flange 65 near the discharge end thereof. A semicircular slot 66 is provided in the body 63 immediately downstream of the flange 64 for receiving a semicircular, internally threaded insert 67. The insert 67 includes a section 68 of thread on the interior thereof for engaging a helical groove 69 in the nozzle body 5. Thus, the nozzle body 5 is placed in the sleeve 6, and the insert 67 is placed in the slot 66. The insert 67 is held in position by a retaining band or clip 70, the hooked ends 72 of which engage notches 73 in the insert 67. When the sleeve 6 and all external parts attached thereto, including the inner and outer shells 8 and 9, respectively, are moved as a unit (rotated on the fixed nozzle body 5) beyond the outlet end of the tube 2, the water pattern becomes more divergent (Fig. 11) and when moved in the other direction to a position in which the discharge end 33 of the tube 2 is inside the sleeve 6 (Figs. 2 and 10), the water pattern becomes more cylindrical. Water discharged from the tube 2 impinges upon the sleeve 6, and instead of flaring is discharged in a more or less cylindrical tube from the sleeve 6. In order to facilitate understanding, the movement shown in the schematic drawings (Figs. 10 and 11) is somewhat exaggerated.

The flange 65 includes a concave, annular groove for receiving an O-ring 75. Shoulders 76 are provided on the trailing end of the sleeve 6 for rotatably supporting the plastic turbine 7 on the sleeve. The turbine 7 is defined by a ring 77 with generally L-shaped blades 78 extending outwardly therefrom. The outer ends of the blades 78 are triangular in cross section with bevelled outer edges. The turbine 7 is used to atomize the water discharged from the tube 2. The water striking the blades 78 causes the turbine to rotate rapidly, and consequently the blades chop the water into the fine droplets required to make snow. The turbine 7 is retained in position by the shoulder 79 of a retainer ring 80. Screws 82 pass through diametrically opposed holes 83 in the ring 80 into the flange 65 of the sleeve 6. An O-ring 84 seals the ring 80 in the inner shell 8.

The sleeve 6 is surrounded by the inner shell 8, which is held thereon by radially extending set screws 86 (Fig. 14) which engage the flange 64. An O-ring 87 provides a seal between the upstream end of the shell 8 and the sleeve 6. An annular flange 89 on the upstream end of the inner shell 8 receives screws 90 and 91 (Figs. 1, 2 and 15) for retaining the cylindrical outer shell 9 on the inner shell 8, and for adjusting the position of the outer shell on such inner shell, respectively. For such purpose, the screws 91 are jack screws. By loosening the screws 90, the screws 91 can be rotated to change the spacing between the flange 8 and the downstream end 93 of the outer shell 9. By again tightening the screws 90 the outer shell 9 is fixedly connected to the inner shell 8.

The cylindrical body 95 of the inner shell 8 and the recessed interior of the body 96 of the outer shell 9 define an air chamber 97 (Figs. 2 and 15) for receiving air from a source of compressed air (not shown) via a hose 99 and an inlet coupler 100 (Figs. 1 and 14). Air is discharged from the chamber 97 via an annular slot 102, which is followed by a flaring mouth 103, whereby the air is caused to flare outwardly during discharge from the gun, i.e. to follow the surface of the flaring mouth 103. An annular groove 105 defining a resonator cavity is provided adjacent the outlet end 106 of the body 96. As indicated by the broken lines 108 in Fig. 14, the outer shell 9 can end immediately downstream of the discharge passage 102.

When using the above described gun, the water and air are discharged separately from the gun for mixing downstream of the gun. There are two parameters which have been given special consideration, namely the power of the water jet or stream, and the power of the compressed air jet or stream. Whereas higher pressures result in better reach (or throw) for water, air is much lighter than water and its reach at, e.g. 100 psi is minimal compared to water at the same pressure. It occurred to the present inventor that it is not a good approach to mix air and water internally prior to

discharge as a mixture as is being done with existing guns. The friction losses are much smaller when the air and water are discharged separately from the gun. With a fixed orifice size using an internal mix gun, as water flow increases air flow decreases. This characteristic has the undesirable result of larger droplets of water at higher flow rates.

By maintaining the fluids separate until discharge the maximum momentum energy of the water is efficiently utilized to achieve better reach and atomization, i.e. increased snowmaking capacity. Optimum air flow exit velocity is achieved to improve nucleation due to refrigerating properties of the expanding air at higher velocities. A low constant airflow volume (approximately 200 cfm) compared to the high variable flow of existing guns results in less noise. Thile the use of a turbine 7 is preferred, because water passing through the valve is atomized, the turbine can be omitted. The use of the spinning teeth 7 turbine results in a wide annular water curtain. The self-carrying properties of the water results in reduced energy consumption compared to the use of a homogeneous mixture, especially when water pressures can be higher than air pressure.

The annular air stream expands and its velocity is reduced to that of the water stream. The air stream acts as a water droplet carrier for the first droplets exiting the plume to reduce the dribbling effect. Such first droplets are finely atomized and carried away by the high peripheral air velocity. The use of a flaring mouth 103 in the gun shapes the annular air stream and provides a base for an annular resonator cavity 105. The use of an annular resonator cavity 105 creates a sonic field at the mouth of the gun. Resonant vibrations developing in the cavity are transmitted through the air stream into the wide annular water curtain. The resonant vibrations enhance water atomization already occurring downstream of the water discharge valve (disc 4), but with much less energy than required by direct contact of compressed air with water (or a mixture of compressed air and

water). The high frequency waves produced by the resonator cavity 105 result in a chopping effect which breaks the liquid stream into extremely small droplets.

The use of the gun permits the use of a constant air supply independently of ambient air temperature. The energy supply is constant as is the case with fan type machines. Water volume is controlled using a valve in the gun rather than by making water pressure adjustments (as is done in existing guns). Thus high water pressure can be maintained at marginal temperatures when the pressure is required to produce good quality snow.

Finally, the energy requirements of the gun of the present invention are only slightly higher than those for fan type machines, and are substantially lower than those for the best performing existing compressed air guns.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A snowmaking gun comprising:

(a) casing means including

(i) outer shell means,

(ii) inner shell means defining an air chamber and an annular air discharge slot with said outer shell means;

(b) tube means extending substantially entirely through said inner shell means for receiving water from a source of water under pressure and for discharging the water from the gun;

(c) valve means at the outlet end of said tube means for controlling the volume of water flowing through said tube means, and shaping the water into an annular stream of small droplets for discharge into the center of the annular stream of air exiting said air discharge slot for mixing with said stream of air downstream of the discharge end of the gun for producing snow, temperature permitting.

2. A snowmaking gun according to claim 1, including turbine means at said outlet end of said valve means for promoting atomizing of the water into small droplets, said turbine means being located immediately upstream of said air discharge slot.

3. A snowmaking gun according to claim 2,including coupler means for connecting an inlet end of said tube means to a source of water under pressure, said valve means including guide rod means connected at one end to said coupler means and slidably supporting said tube means; and disc means on the other end of said rod means partially closing the outlet end of said tube means for creating the annular stream of water.

4. A snowmaking gun according to claim 3, wherein said valve means includes tubular nozzle body means on

the inlet end of said tube means and connected at one end to said coupler means; pin means between said tube means and said nozzle body means permitting longitudinal movement while preventing rotation of said tube means in said nozzle body means; and cam means in said nozzle body means engaging said tube means, whereby rotation of said cam means causes longitudinal movement of said tube means relative to said disc means to vary the size of the water discharge opening and consequently the volume of water flowing through said water discharge opening.

5. A snowmaking gun according to claim 4, including control ring means rotatable on said nozzle body means and engaging said cam means for rotating the latter in said nozzle body means.

6. A snowmaking gun according to claim 3, including sleeve means on an end of said nozzle body means remote from said coupler means, said sleeve means being concentric with and engaging the outlet end of said tube means, longitudinal movement of said sleeve means with respect to said tube means serving to alter the initial flow pattern of the stream of water between generally cylindrical and diverging; and latch means on said sleeve means for locking the sleeve means on the nozzle body means to provide a chosen flow pattern for the stream of water.

7. A snowmaking gun according to claim 6, wherein said latch means includes helical groove means in said nozzle body means, and arcuate gear segment means for engaging said groove means to lock the sleeve means in one position on the nozzle body means.

8. A snowmaking gun according to claim 6, wherein said turbine means includes a ring rotatably mounted on the downstream end of said sleeve means, and teeth extending axially inwardly from the ring for intercepting the stream of water, whereby the water pressure causes rapid rotation of the ring and chopping of the water into small droplets by teeth.

9. A snowmaking gun according to claim 1,

wherein said outer shell means includes flaring throat means at the discharge end thereof for causing the air to follow a flaring path of travel when exiting the gun.

10. A snowmaking gun according to claim 9, including resonator cavity means in said throat means for generating resonant vibrations in the air stream to enhance water atomization.

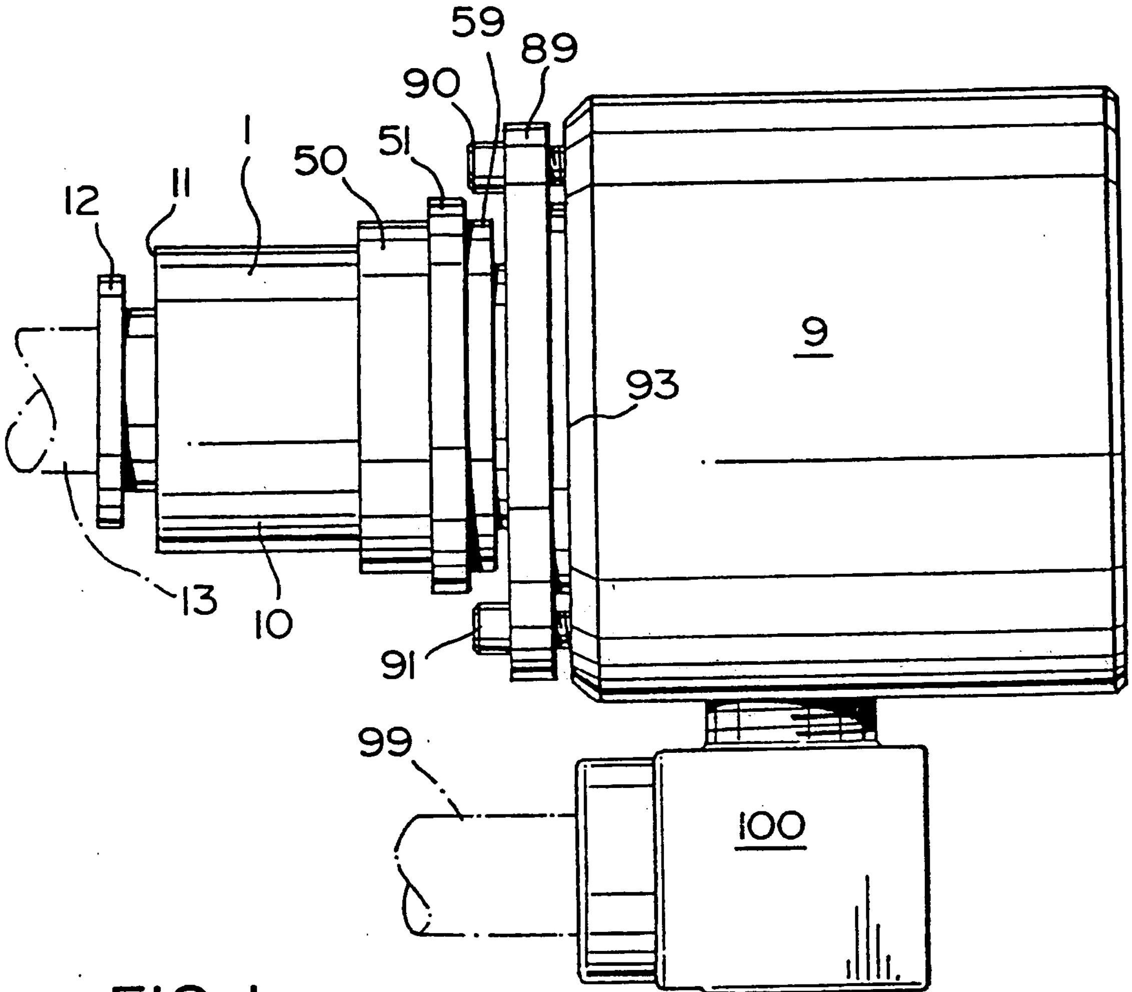

FIG. 1

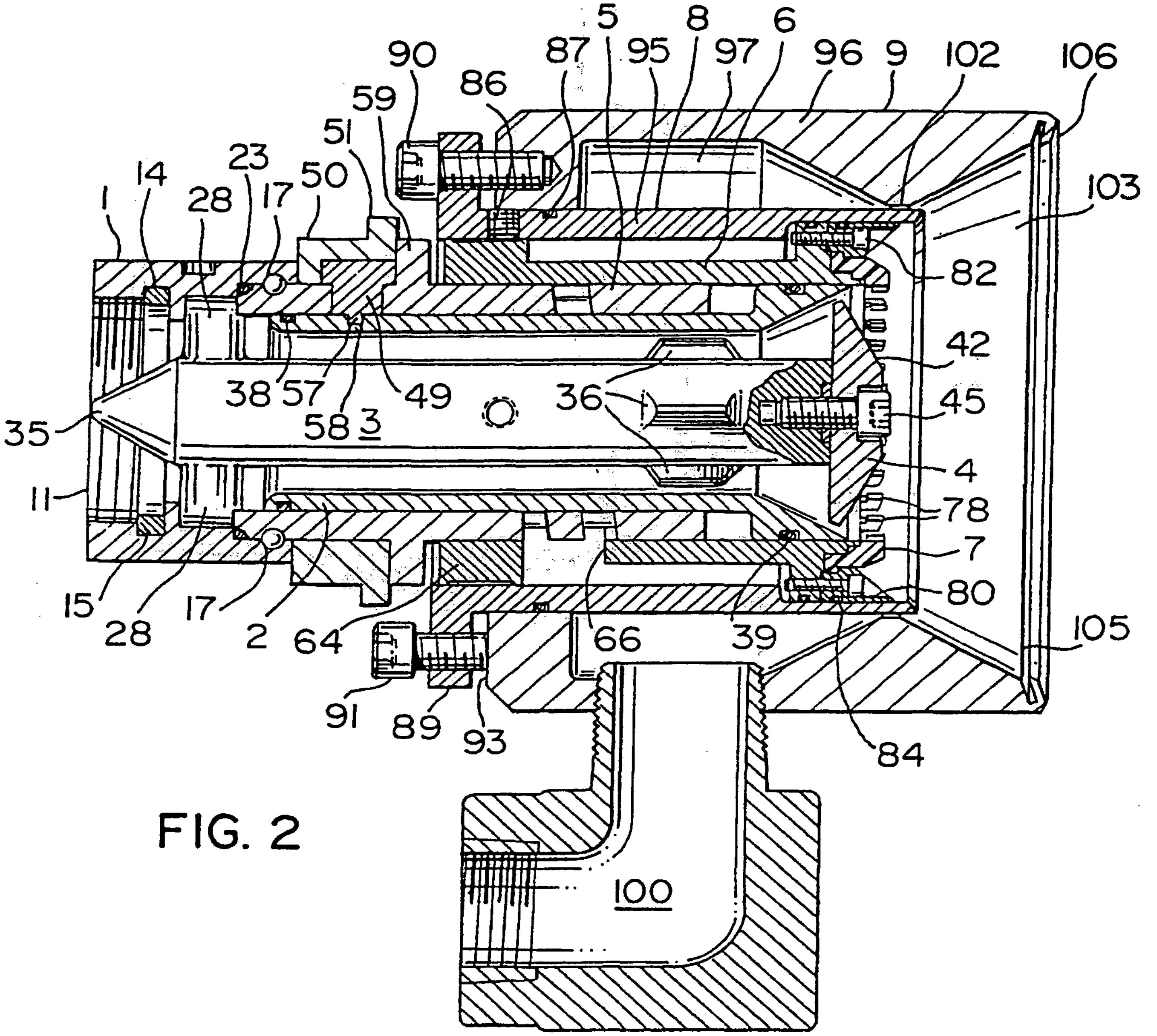

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FIG. 2

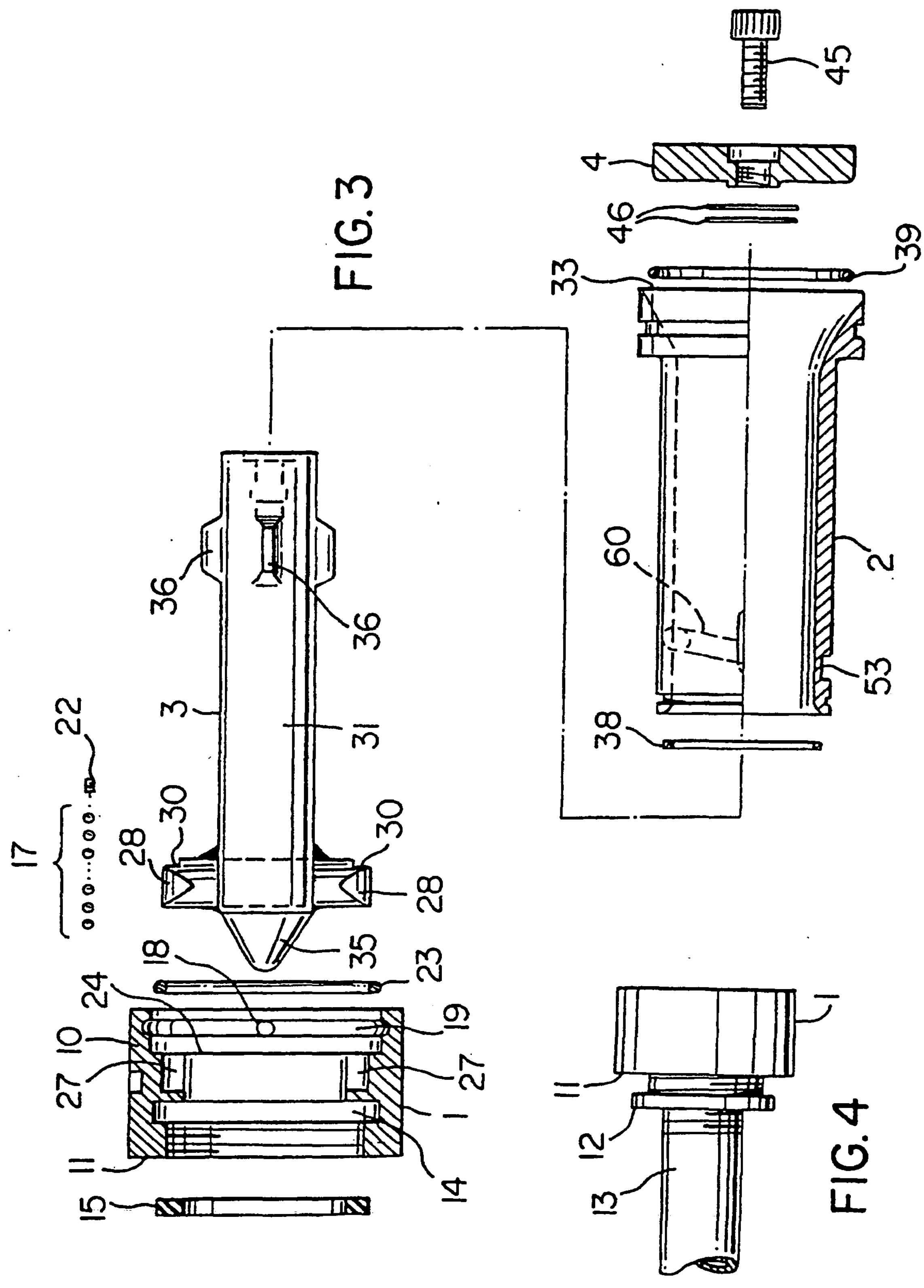
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FIG. 3

FIG. 4

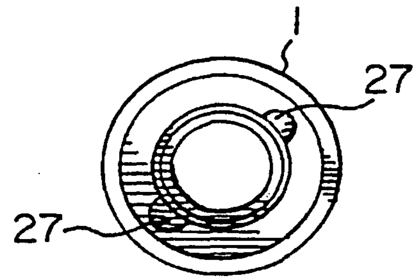

FIG. 5

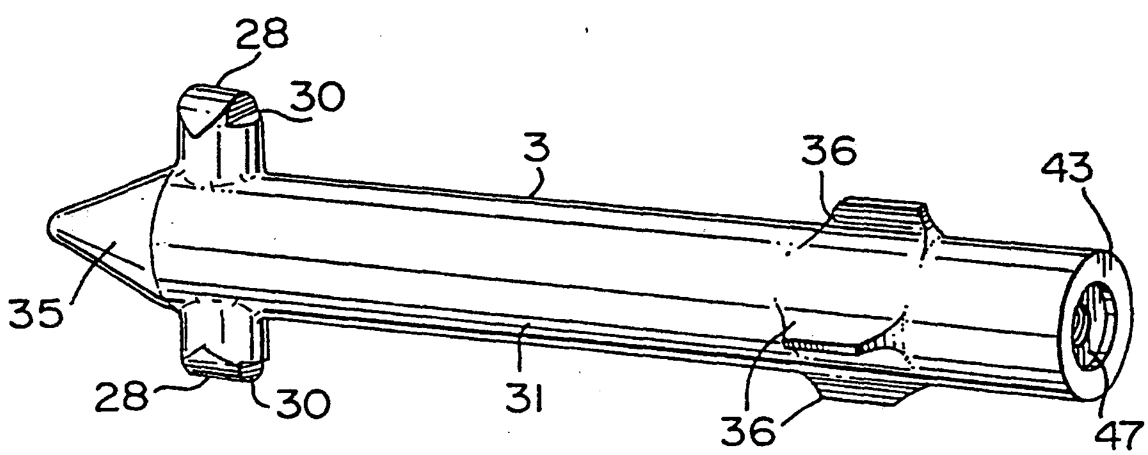

FIG. 6

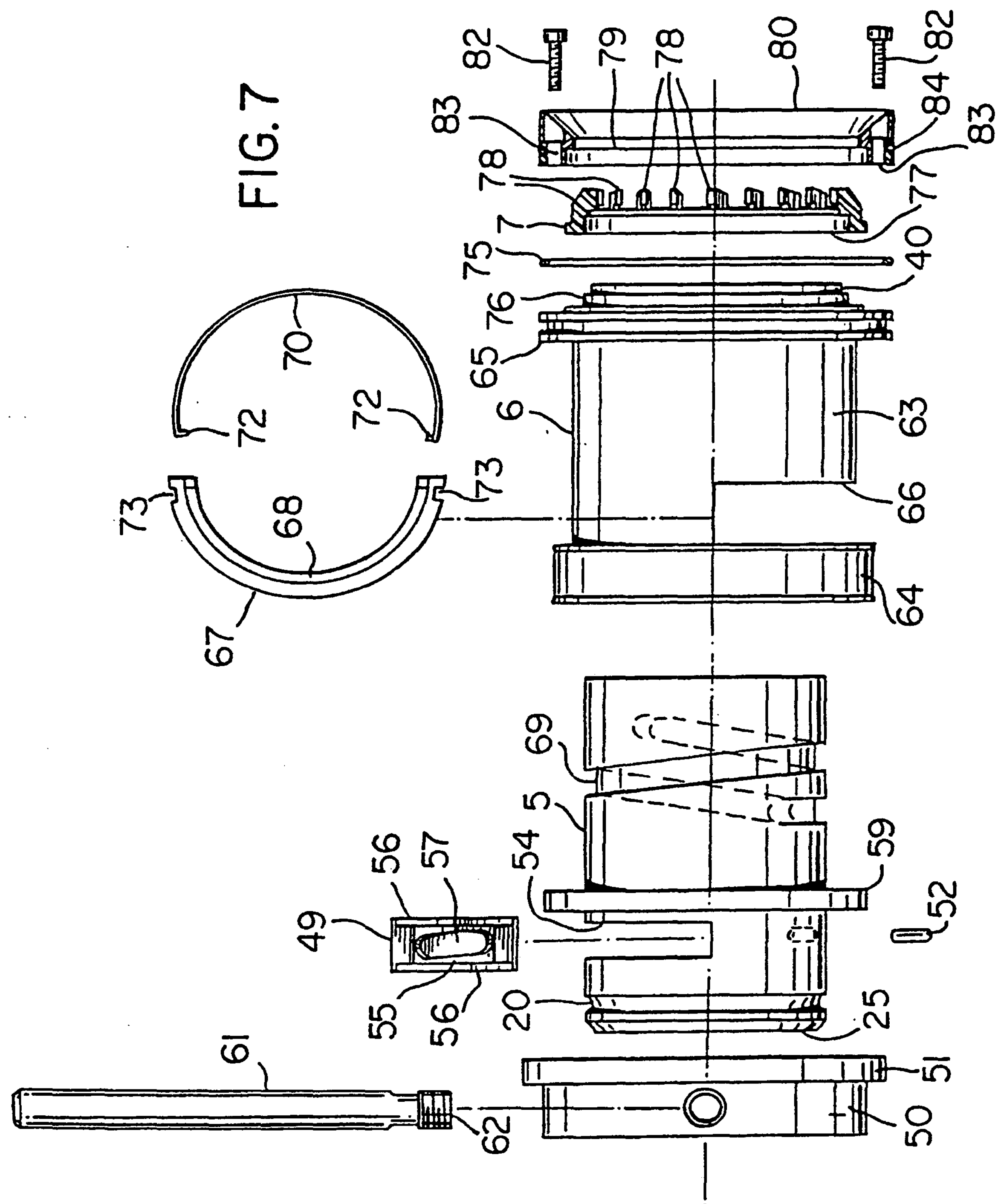
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FIG. 7

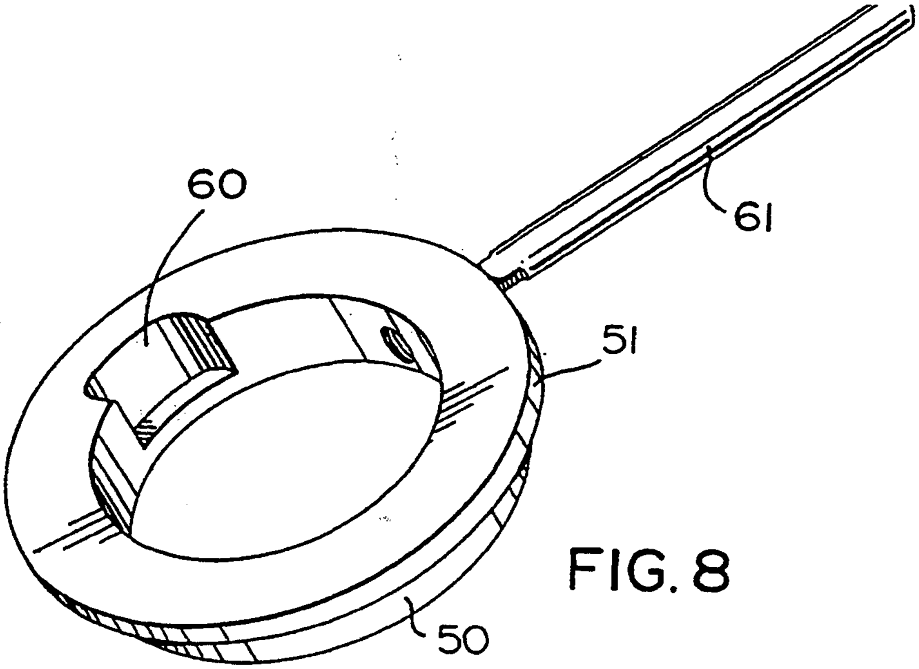

FIG. 8

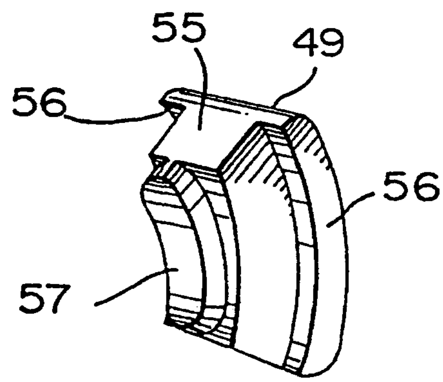

FIG. 9

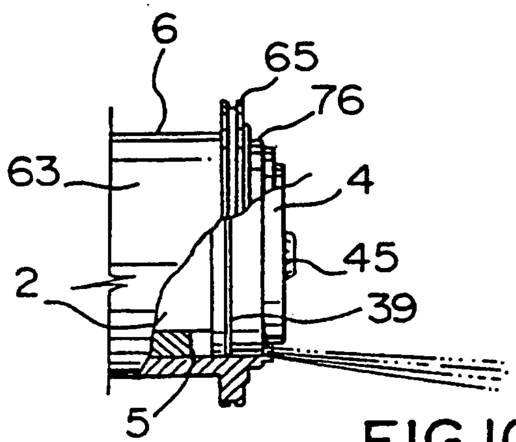

FIG.10

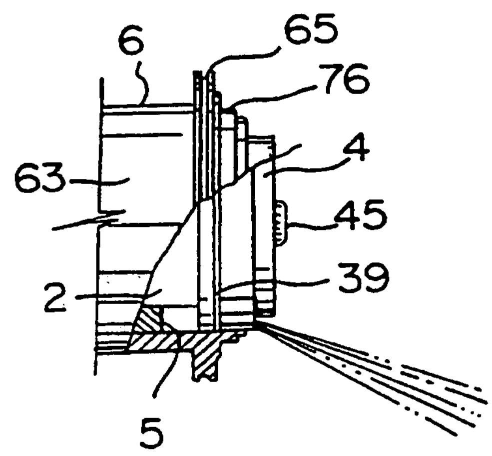

FIG.11

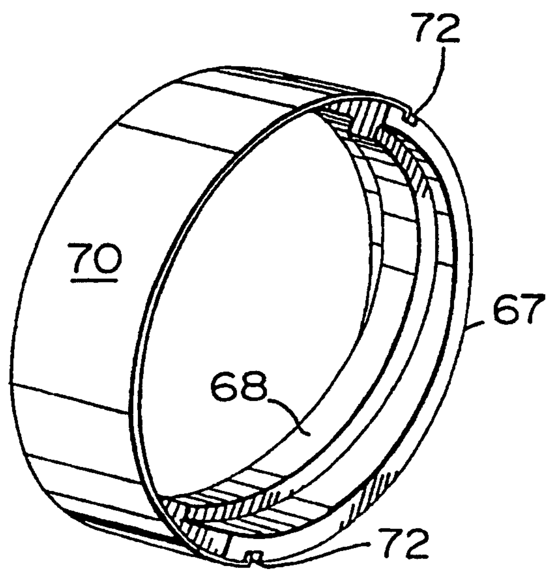

FIG.12

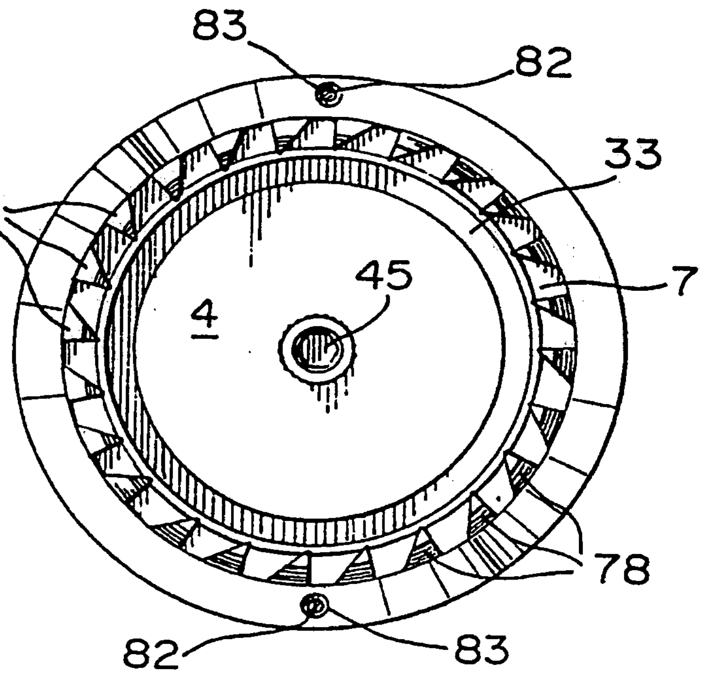

FIG.13

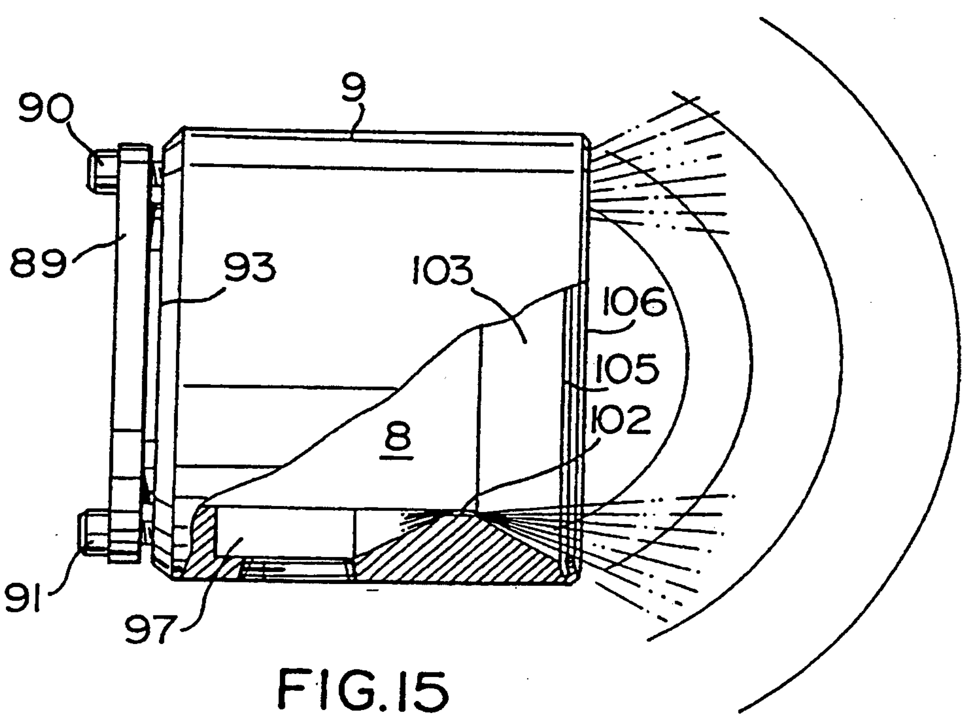

FIG.15

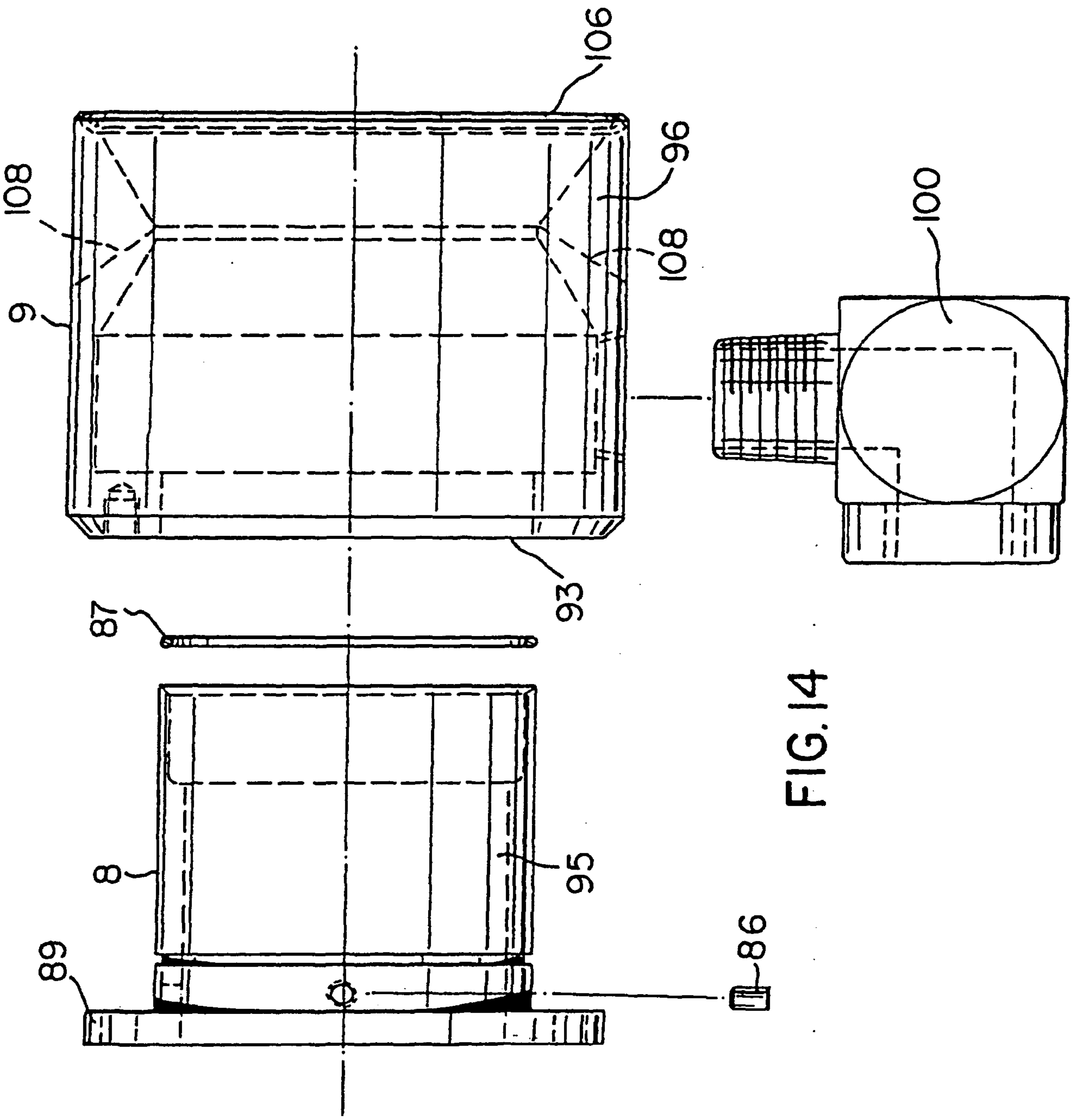

FIG. 14

INTERNATIONAL SEARCH REPORT

Inter. ...al Application No
PCT/CA 93/00469

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 F25C3/04 B05B7/06 B05B1/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 F25C B05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,A,16 01 081 (LINDE) 10 December 1970 see page 5, last paragraph - page 7, paragraph 1; figures 1-2 ---	1
A	US,A,3 387 791 (ALLENBAUGH) 11 June 1968 see column 5, line 61 - column 11, line 66; figures 1-18 ---	1-8
A	US,A,3 533 559 (CAIRD) 13 October 1970 see column 1, line 63 - column 3, line 36; figures 1-7 ---	1,3,4
A	US,A,2 733 962 (CAIRD) 7 February 1956 see column 1, line 45 - column 2, line 64; figures 1-2 ---	1,3,4
A	US,A,3 301 485 (TROPEANO) 31 January 1967 ---	
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
28 January 1994	7. 02. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Boets, A

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,3 908 903 (BURNS) 30 September 1975 ---	
A	US,A,4 730 774 (SHIPPEE) 15 March 1988 -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. ɔnal Application No
PCT/CA 93/00469

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
DE-A-1601081	10-12-70	NONE		
US-A-3387791		NONE		
US-A-3533559	13-10-70	NONE		
US-A-2733962		NONE		
US-A-3301485		NONE		
US-A-3908903	30-09-75	AU-A-	7795675	12-08-76
		CA-A-	1009857	10-05-77
		DE-A,C	2505483	14-08-75
		FR-A,B	2260763	05-09-75
		JP-C-	1242926	14-12-84
		JP-A-	50114652	08-09-75
		JP-B-	59011835	17-03-84
US-A-4730774	15-03-88	NONE		